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Communication & competition

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Abstract Charness and Dufwenberg (Am. Econ. Rev. 101(4):1211–1237, 2011) have recently demonstrated that cheap-talk communication raises efficiency in bilateral contracting situations with adverse selection. We replicate their main finding and extend their design to include competition between agents. We find that communication and competition act as "substitutes:" communication raises efficiency in the absence of competition but not with competition, and competition raises efficiency without communication but lowers efficiency with communication. We briefly review some behavioral theories that have been proposed in this context and show that each can explain some but not all features of the observed data patterns. Our findings highlight the fragility of cheap-talk communication and may serve as a guide to refine existing behavioral theories.

Keywords Cheap talk · Adverse selection · Competition · Guilt aversion · Lie aversion · Inequality aversion · Reciprocity

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1 Introduction

It is well known that efficient contracting may be hampered by adverse selection problems that arise when outputs depend on privately known talents or types. Besides an impressive theoretical literature that addresses the design of optimal contracts in the presence of adverse selection (e.g., Bolton and Dewatripont 2005), alternative solutions based on insights from behavioral economics and laboratory experiments have recently been proposed (e.g., Fehr et al. 2007). In particular, experimental studies have demonstrated that "cheap talk," i.e. non-binding and costless communication, can enhance efficiency (Charness and Dufwenberg 2006, 2011) and can be more effective than monetary incentives (Brandts and Cooper 2007). Plausible explanations that have been put forth are that cheap talk messages contain implicit promises that are costly to break when agents get disutility from lying or from letting others down.

Much of this recent literature, however, focuses on bilateral relationships between a single principal and a single agent. This is obviously different from many real-world settings, e.g. when multiple job applicants compete for a single job (especially in times of a recession). It is conceivable that competition will change the nature of the messages exchanged, or the propensity with which promises are kept. In addition, implicit promises may have less impact when a principal receives similar messages from more than one agent. It is, therefore, natural to ask whether cheap-talk communication is still effective in promoting efficient contracting when competition exists.

To address this question, we vary the possibility of communication in the one-shot principal-agent game studied by Charness and Dufwenberg (2011) and in an extension where the principal selects one of two agents before playing the game. This variation of the game defines our competition treatments. Our experiment replicates the main finding of Charness and Dufwenberg (2011). We find that in the "no-competition" treatments, communication raises efficiency. We also find that in the "no-communication" treatments, competition raises efficiency. Thus, by themselves, communication and competition positively affect efficiency. However, compared to treatments with competition or communication only, efficiency is *lower* in a treatment with both communication and competition. In other words, competition and communication act as substitutes. Communication raises efficiency without competition but not with competition. Likewise, competition raises efficiency without communication but lowers efficiency with communication.

We review related experimental work and several behavioral theories that have been proposed in this context. We find that lie aversion, guilt aversion, inequality aversion, and reciprocity all capture some but not all features of the data. We expressly do not propose an alternative theory but rather hope that our findings will stimulate further theoretical work in this area.

The remainder of the paper is organized as follows. Section 2 describes our experimental design based on the principal-agent game with hidden information. In Sect. 3 we report the effects of communication and competition. We also correlate messages with outcomes to provide additional insights into behavior. Section 4 briefly discusses related experiments and evaluates several behavioral theories. Section 5 concludes.

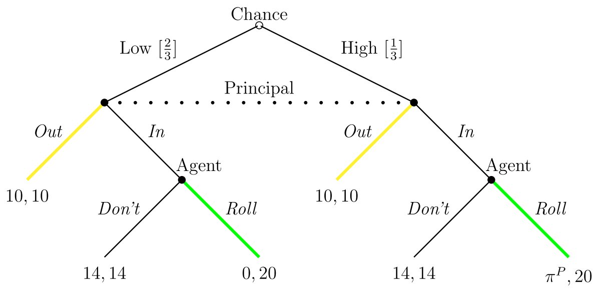

Fig. 1 A principal-agent game with hidden information. In the no-die-roll ("NDR") version $\pi^P = 20$ for sure while in the with-die-roll ("WDR") version $\pi^P = 24$ with probability 5/6 and $\pi^P = 0$ with probability 1/6

2 Experimental design

2.1 A simple principal-agent game

The experiment employs simple variations of the principal-agent game with hidden information as proposed by Charness and Dufwenberg (2011). The principal needs to hire an agent to complete a project, which can be either a simple project at a wage of 14, or a difficult project at a wage of 20. Agents can be either of "Low" type (with probability 2/3) or of "High" type (with probability 1/3). Both types of agents can complete the simple project while only the high-type agent can successfully complete the difficult project. The contract cannot be conditioned on the agent's type, which is private information; the principal only knows the *ex ante* probabilities that an agent is of low or high type.

The game tree is summarized in Fig. 1.[1] If the principal chooses not to hire ("Out") then both the principal and the agent get their outside-option payoffs of 10. When the principal chooses to hire ("In") the outcome depends on who accepts the difficult project. If a low-type agent selects the difficult project ("Roll") then he fails and the principal gets 0. If a high-type agent selects the difficult project then in the with-die-roll ("WDR") version of the game the project is completed successfully with probability 5/6 and the principal receives 24, otherwise the principal gets nothing. In the no-die-roll ("NDR") version of the game the principal gets (the expected value) 20 for sure. (These two versions are introduced to test different models of guilt, as explained in Sect. 4 below.) Finally, if the simple project is selected ("Don't Roll") by either type of agent then the principal receives 14.

Socially optimal contracts are possible when information is complete, i.e. when the contract can be conditioned on the agent's type. In this case, the principal hires a low-type agent to complete the simple project or a high-type agent to complete the difficult project. It will be useful to compare the outcomes observed in the experiment to this efficient benchmark.

Definition The efficient outcomes are ("In", "Don't Roll") when the agent is of low type and ("In", "Roll") when the agent is of high type. All other outcomes are inefficient.

[1] We doubled the payoffs in Charness and Dufwenberg (2011) to make the monetary incentives more salient.

Table 1 The experimental design varies whether there is competition between agents and whether one-sided communication from the agent(s) to the principal is possible. In addition, in the no-competition treatments the principal's payoff is 20 for sure in the no-die-roll treatments and it is 24 with chance 5/6 and zero otherwise in the with-die-roll treatments

Treatment	Competition	Communication channel	Group size	# of groups	# of subjects
2NC-WDR	No	None	2	24	48
2C-WDR	No	B → A	1	24	48
2NC-NDR	No	None	2	25	50
2C-NDR	No	B → A	1	23	46
3NC-WDR	Yes	None	3	39	117
3C-WDR	Yes	B1 → A, B2 → A	3	37	111

When contracts are efficient, the *ex ante* expected payoffs are readily computed to be 16 for the principal and 16 for the agent. These payoffs are higher than those that result when contracts cannot be conditioned on the agent's private information. With selfish and risk neutral agents, the prediction is that both low-type and high-type agents will choose "Roll," and, hence, the best response for the principal is to choose "Out," resulting in payoffs of 10 for both the principal and the agent.[2] The setting of Fig. 1 therefore captures the adverse selection problem that hinders efficient contracting.

2.2 Design and procedures

Table 1 summarizes the different treatments of the experiment, which vary by whether or not there is agent competition (group size two or three), whether or not communication is allowed ("C" or "NC"), and whether or not the principal's payoff when a high-type agent chooses "Roll" is uncertain ("NDR" or "WDR"). Communication is one-way, e.g. in "2C-NDR" or "2C-WDR" the agent can send free-form messages to the principal but not vice versa. In the no-competition treatments with group size equal to two the principal is paired with a single agent while in the competition treatments with a group size of three there is an additional agent. In the competition treatments the principal has to select one of the two agents prior to playing the game shown in Fig. 1. In "3C-WDR" both agents can send free-form messages to the principal to influence the principal's selection while this is not possible in treatment "3NC-WDR".[3] Communication is again one-way and is delivered via two independent chat windows so that agents cannot observe or influence each other's messages.

[2] Choosing "In" yields an expected payoff of only $1/3 \times 5/6 \times 24 = 20/3$ for the principal.

[3] Stigler (1987, p. 531) defines competition as "a rivalry between individuals ... that arises whenever two or more parties strive for something that all cannot obtain." Treatment "3C-WDR" captures this definition while keeping the incentives for the principal and the selected agent the same as in the "2C-WDR" treatment. This allows us to isolate the effect of competition when communication is possible. Furthermore, the comparison between treatments "3C-WDR" and "3NC-WDR" allows us to measure the effect of communication in the presence of competition.

To create a salient economic incentive to compete, the outside option payoff for the agent who is not selected is 5, while for the agent who is selected but not hired it is 10. Note that post-selection the game being played is exactly the same for the principal and selected agent as in the no-competition case.

We recruited a total of 420 subjects from the University of Zürich and the neighboring ETH. The sessions without communication typically took about half an hour and the sessions with communication took about an hour, including the instruction and payment phases. The reason that the experiments were quick is that there was only a single period of play. Average earnings were 23 CHF including a 10 CHF show-up fee at an exchange rate of roughly 1 CHF for \$1. The experimental instructions closely follow those of Charness and Dufwenberg (2011), see online supplementary material.[4]

3 Results

We first discuss the aggregate outcomes in the different treatments and then provide an analysis of the messages that were sent in the communication treatments.

3.1 Outcomes

We start by comparing the outcomes of our no-competition treatments (with group size two) to those of Charness and Dufwenberg (2011) to check whether we replicate their findings. The left and middle panels of Fig. 2 show the fraction of "In" choices made by the principal and the fraction of "Don't Roll" choices made by the low-type agent respectively. We do not separately show the percentage of "Roll" choices for the high-type agents, which, like in the Charness and Dufwenberg (2011) study, was 100 % in all treatments. Each panel shows the results for the with-die-roll ("WDR") and no-die-roll ("NDR") treatments separately and combined ("Pooled") as well as the results from the Charness and Dufwenberg (2011) study (labeled "C&D"). For each data set, the left bar ("NC") pertains to the no-communication treatment and the right bar ("C") to the communication treatment. The right panel in Fig. 2 shows the predicted fraction of efficient outcomes based on the choice data and, in the communication treatments, the messages sent. We use the predicted rather than the observed fraction of efficient outcomes to correct for any differences in outcomes unrelated to the subjects' decisions.[5]

[4]One difference is that our experiments were computerized using zTree (Fischbacher 2007). In all treatments with communication, subjects could choose to remain silent by simply clicking the continue button.

[5]For instance, agents' types were randomly determined by the program and the fraction of high-type agents varied from 28.6 % to 41.7 % across treatments. To correct for this variability, the predicted fraction of efficient outcomes, $p^{In}(\frac{1}{3}+\frac{2}{3}p^{DR})$, uses the ex ante probabilities for each type. Here p^{In} denotes the principal's "In" rate and p^{DR} the low-agent's "Don't Roll" rate. In the communication treatments, the "In" and "Don't Roll" rates may depend on the agent's message, m, which, in turn, may depend on the agent's type. The predicted fraction of efficient outcomes now becomes $\sum_m p^{In}(m)(\frac{1}{3}P_H(m)+\frac{2}{3}P_L(m)p^{DR}(m))$ where $P_L(m)$ and $P_H(m)$ are the probabilities that a low-type or high-type agent sends message m respectively. See Sect. 3.2 for a detailed discussion on how messages were classified and how the fraction of efficient outcomes were calculated for the case with agent competition.

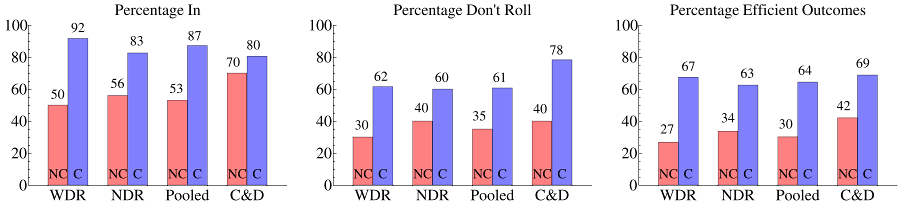

Fig. 2 The *left panel* displays the "In" rates, the *middle panel* the "Don't Roll" rates, and the *right panel* the predicted fraction of efficient outcomes for the no-competition treatments. In each panel, the "NC" bar refers to the no-communication treatment and the "C" bar to the communication treatment. The data from the Charness and Dufwenberg (2011) study are labeled "C&D" and the data of the with-die-roll and no-die-roll treatments are labeled "WDR" and "NDR" respectively. The "Pooled" data represent the combined data of the with-die-roll and no-die-roll treatments

As can be seen from Fig. 2, the "In" rates, "Don't Roll" rates, and predicted percentages of efficient outcomes are very similar for the "NDR" and "WDR" treatments, whether or not communication is allowed. Furthermore, they are all similar to the corresponding rates for the Charness and Dufwenberg (2011) study. Indeed, formal statistical tests reveal no significant differences (at the 10 %-level) for either the "In" rate, "Don't Roll" rate, or the predicted percentage of efficient outcomes with or without communication.[6]

Finding 1 Our no-competition treatments replicate Charness and Dufwenberg (2011)'s finding that communication enhances efficiency.

Finding 2 The results from the no-die-roll and with-die-roll treatments are not significantly different with or without communication.

Since there are no significant differences between the "NDR" and "WDR" treatments we will consider only the pooled data in the remainder of this section. To avoid confusion, we drop the "NDR" and "WDR" labels and refer to the pooled data from the two-person communication treatments as "2C" and to those from the no-communication treatments as "2NC." Figure 3 shows the "In" rates, "Don't Roll" rates, and percentage of efficient outcomes for these pooled data sets and the corresponding rates for the competition treatments, which are now labeled "3NC" and "3C."

Note that the three panels of Fig. 3 show a similar pattern: the "In" rate, the "Don't Roll" rate, and the percentage of efficient outcomes are high for the "2C" and "3NC" treatments and low for the "2NC" and "3C" treatments. Formal statistical tests reported in Table 2 confirm that competition raises efficiency without communication

[6]More specifically, a two-sided proportion test shows no significant difference at the 10 % level between the "In" rates in "NDR" vs "WDR", "NDR" vs "C&D", "WDR" vs "C&D", and "pooled" vs "C&D", for both the "NC" and "C" treatments respectively. The same no-difference result holds for the "Don't Roll" rate and the percentage of efficient outcomes in both the "NC" and "C" treatments respectively. All p-values reported in this paper are two-sided, unless otherwise stated.

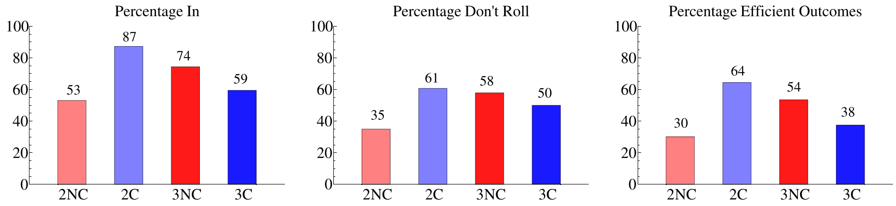

Fig. 3 The *left panel* displays the "In" rates, the *middle panel* the "Don't Roll" rates, and the *right panel* the predicted fraction of efficient outcomes for all treatments

Table 2 Results from a two-sided proportion test to evaluate the effects of communication and competition. The "Z stat" reflects the test of equal proportions across treatments with p-values at 10 %, 5 %, and 1 % indicated by *, **, and ***, respectively

Treatment	A's In Rate			B's Don't Roll Rate			% Efficient Outcome		
	C	NC	Z stat	C	NC	Z stat	C	NC	Z stat
$N = 2$	41/47 (87 %)	26/49 (53 %)	3.65***	17/28 (61 %)	7/20 (35 %)	1.76*	64.4 %	30.1 %	3.37***
$N = 3$	22/37 (59 %)	29/39 (74 %)	−1.38	6/12 (50 %)	11/19 (58 %)	−0.43	37.5 %	53.5 %	−1.40
Effect of competition Z stat	−2.92***	2.05**		−0.63	1.43		−2.45**	2.22**	

(3NC vs 2NC) but it lowers efficiency with communication (3C vs 2C).[7] Likewise, communication raises efficiency in the absence of competition (2C vs 2NC) but not with competition (3C vs 3NC).[8] In other words, communication and competition act as "substitutes."

Finding 3 Competition raises efficiency without communication but lowers efficiency with communication.

Finding 4 Communication raises efficiency without competition but not with competition.

This substitute relationship may result from the fact that competition affects the messages sent or the extent to which the principal relies on the messages, or possibly both. To explore this issue, we next provide a detailed analysis of the messages exchanged in the different treatments.

[7]Efficiency rises from 30.1 % in 2NC to 53.5 % in 3NC ($p = 0.026$) but it falls from 64.4 % in 2C to 37.5 % in 3C ($p = 0.014$).

[8]Efficiency rises from 30.1 % in 2NC to 64.4 % in 2C ($p < 0.001$) but it falls from 53.5 % in 3NC to 37.5 % in 3C ($p = 0.162$). Had we based our null hypotheses on Charness and Dufwenberg's (2011) finding that communication raises efficiency then this null hypothesis would be rejected in a one-sided test ($p = 0.081$). Note that Charness and Dufwenberg (2011) use a one-sided test to evaluate the effect of communication on efficiency.

Table 3 Messages and outcomes in the communication treatments without competition. The data from the Charness and Dufwenberg (2011) study are labeled "C&D" and the data from the with-die-roll and no-die-roll treatments are labeled "WDR" and "NDR" respectively. The "Pooled" data represent the combined data of the with-die-roll and no-die-roll treatments

C & D (2011)		NP	LD	HR	Total	2C (pooled)		NP	LD	HR	Total
Low	Out	4	1	0	5	Low	Out	2	2	1	5
	In, R	0	0	5	5		In, R	4	2	5	11
	In, DR	4	13	1	18		In, DR	3	13	1	17
	Total	8	14	6	28		Total	9	17	7	33
		28.6 %	50.5 %	21.4 %	100.0 %			27.3 %	51.5 %	21.2 %	100.0 %
High	Out	2	0	1	3	High	Out	0	0	1	1
	In, R	0	2	8	10		In, R	1	0	12	13
	In, DR	0	0	0	0		In, DR	0	0	0	0
	Total	2	2	9	13		Total	1	0	13	14
		15.4 %	15.4 %	69.2 %	100.0 %			7.1 %	0.0 %	92.9 %	100.0 %

2C-WDR		NP	LD	HR	Total	2C-NDR		NP	LD	HR	Total
Low	Out	1	0	1	2	Low	Out	1	2	0	3
	In, R	1	2	2	5		In, R	3	0	3	6
	In, DR	2	5	1	8		In, DR	1	8	0	9
	Total	4	7	4	15		Total	5	10	3	18
		26.7 %	46.7 %	26.7 %	100.0 %			27.8 %	55.6 %	16.7 %	100.0 %
High	Out	0	0	0	0	High	Out	0	0	1	1
	In, R	1	0	8	9		In, R	0	0	4	4
	In, DR	0	0	0	0		In, DR	0	0	0	0
	Total	1	0	8	9		Total	0	0	5	5
		11.1 %	0.0 %	88.9 %	100.0 %			0.0 %	0.0 %	100.0 %	100.0 %

3.2 Messages

We employed two independent coders to classify the free-form messages using the scheme developed by Charness and Dufwenberg (2011). In particular, there are three basic message types: "NP" for no promise, "LD" when a low-type agent discloses her type and promises to choose "Don't Roll," and "HR" when a high-type agent discloses her type and promises to choose "Roll."[9]

Table 3 provides an overview of the messages sent by each agent type in our no-competition treatments and compares them with those from the Charness and

[9] As in Charness and Dufwenberg (2011) most, but not all, messages can be captured with this coding scheme. Other types of messages are "PL" when a low-type agent only discloses her type with no promise about the action she will take, "PR" when the agent only promises to "Roll" without disclosing her type, "PH" when the agent claims to be of high type with no promise about the action, and "DR" when the agent promises to choose "Don't Roll" without disclosing her type. The first two messages were classified as "NP," the third message as "HR" and the fourth message as "LD." Finally, empty talk messages and no messages are included in "NP."

Dufwenberg (2011) study. In each box in Table 3, the row labeled "Total" shows the total number of times each message was used, while the percentage below the box expresses this as a frequency. Using the Fisher's exact test to compare the distributions of messages types (NP, LD, and HR) reveals no significant differences (at the 10 % level) between the "NDR" and "WDR" messages nor are there significant differences between the pooled messages and the messages from the Charness and Dufwenberg (2011) study.

Finding 5 The frequencies with which the different message types occurred in our communication treatment without competition are not significantly different from those observed by Charness and Dufwenberg (2011).

Finding 6 The frequencies with which the different message types occurred in the no-die-roll and with-die-roll communication treatments without competition are not significantly different.

Table 3 also lists the resulting outcomes by message and agent type. A test of our coding scheme is whether the messages capture everything that the principal knows about the agent, i.e. whether, conditional on the message, the principal's choice is independent of the agent's type.[10] Using a simple proportion test reveals that, conditional on the message received, there are no significant differences (at the 10 % level) between the principal's "In" rate when the message is sent by a low or a high-type agent. This is true for the "2C-NDR" and "2C-WDR" messages as well as for the pooled messages and the messages from the Charness and Dufwenberg (2011) study.

We next compare the messages from the pooled no-competition treatments (labeled "2C") with those from the competition treatment ("3C"), see the top panels of Table 4. First, with or without competition, messages sent by low-type agents differ significantly from those sent by high-type agents.[11] Moreover, messages differ significantly between the no-competition and competition treatments.[12] In particular, for both types of agents there is a shift from the message they predominantly use in the absence of competition ("LD" for a low-type agent and "HR" for a high-type agent) to the "NP" message.[13] The rows labeled "Total" in the top panels of Table 4 show that while the "NP" message is least used (10/47) without competition it is the most frequently used message (32/74) with competition.[14]

[10]For example, in 2C (pooled) sample, the principal chose "In" in 6/7 cases when the low-type agent sent an "HR" message and in 12/13 cases when the high-type agent sent an "HR" message.

[11]The Fisher exact test comparing the NP, LD and HR messages sent by low-type and high-type agents yields $p < 0.001$ for treatment "2C" and $p = 0.010$ for treatment "3C."

[12]For low-type agents the difference is close to being significant with $p = 0.124$, for high-type agents $p = 0.073$, and for the pooled messages $p = 0.041$ using the Fisher exact test.

[13]The proportion of "NP" messages sent by the low-type and high-type agents increases from 27 % to 45 % and from 7 % to 38 % respectively. A two-sided proportion test shows that these increases are significant ($p = 0.09$ for low-type agents and $p = 0.04$ for high-type agents).

[14]In treatment 3C, out of 74 messages there were 32 NP messages that can be broken down as follow: 11 silent, 2 PR messages, 3 PL messages, and 16 empty talk messages. In 2C, out of 47 messages there were 10 NP messages: 1 silent, 3 PL messages, and 6 empty talk messages. A Fisher exact test cannot reject the

Table 4 A comparison of the communication treatments with and without competition. The top panels show the messages sent by each type of agent as well as the low-type agent's and principal's choice frequencies. The top parts of the lower panels show the frequencies with which low-type and high-type agents were matched (in 2C) or selected (in 3C) given the message they sent. The bottom parts of the lower panels show how much low-type and high-type agents contributed to the total percentage of efficient outcomes given the messages they sent

2C	NP	LD	HR	Total	3C	NP	LD	HR	Total
Low	9	17	7	33	Low	24	16	13	53
High	1	0	13	14	High	8	1	12	21
Total	10	17	20	47	Total	32	17	25	74
In	8/10	15/17	18/20	41/47	In	3/9	5/10	14/18	22/37
DR	3/7	13/15	1/6	17/28	DR	0/1	5/5	1/6	6/12
Matched Low	18.2 %	34.3 %	14.1 %	66.6 %	Select Low	20.1 %	22.3 %	21.9 %	64.3 %
Matched High	2.4 %	0.0 %	31.0 %	33.4 %	Select High	8.4 %	1.8 %	25.5 %	35.7 %
Total	20.6 %	34.3 %	45.1 %	100.0 %	Total	28.5 %	24.1 %	47.4 %	100.0 %
Efficiency Low	6.2 %	26.2 %	2.1 %	34.6 %	Efficiency Low	0.0 %	11.2 %	2.8 %	14.0 %
Efficiency High	1.9 %	0.0 %	27.9 %	29.8 %	Efficiency High	2.8 %	0.9 %	19.8 %	23.5 %
Total	8.2 %	26.2 %	30.0 %	64.4 %	Total	2.8 %	12.0 %	22.7 %	37.5 %

Finding 7 When competition is introduced there are fewer messages that contain claims about agents' types.

One explanation is that with competition, low-type agents do not disclose their true types for fear of not being selected and do not claim to be of high type because they are lie averse. The fact that some high-type agents also send "NP" messages might be because they anticipate that "HR" messages are interpreted as lies by low-type agents.

The preponderance of "NP" messages make it harder for the principal to select high-type agents and may negatively affect her decision to choose "In." We first discuss the selection issue. In treatment "2C," given the frequency $P_L(m)$ with which a low-type agent sends message m, the chance that the principal is matched with a low-type agent who sent message m is $P_L^{matched}(m) = \frac{2}{3}P_L(m)$. Similarly, the chance that the principal is matched with a high-type agent who sent message m is $P_H^{matched}(m) = \frac{1}{3}P_H(m)$. These match probabilities are shown in the top part of the lower-left panel. Together with the "In" and "Don't Roll" rates they determine the predicted fraction of efficient outcomes by agent and message type[15] and the overall

null hypothesis that the distributions of message types within the NP category are the same between 2C and 3C ($p = 0.187$). However, there are significantly more NP messages in 3C ($p = 0.013$).

[15]When a low-type agent sends message m, predicted efficiency is $P_L^{matched}(m)p^{In}(m)p^{DR}(m)$ and when a high-type agent sends message m it is $P_H^{matched}(m)p^{In}(m)$.

fraction of efficient outcomes:

$$\sum_{m\in\{\mathrm{NP},\mathrm{LD},\mathrm{HR}\}} p^{In}(m)\big(P_H^{matched}(m) + P_L^{matched}(m)p^{DR}(m)\big) \tag{1}$$

which yields 64.4 % for treatment "2C," see the bottom-left panel of Table 4.

In treatment "3C," the principal can use the messages received to improve the chances of selecting a high-type agent. To analyze this issue we simply record which message was selected by the principal from each of the 37 pairs of messages received. If we order the messages ("NP", "LD", "HR") then the empirical selection frequencies can be conveniently summarized by the following 3×3 matrix

$$P^{select} = \begin{pmatrix} 0.50 & 0.20 & 0.21 \\ 0.80 & 0.50 & 0.29 \\ 0.79 & 0.71 & 0.50 \end{pmatrix}$$

where each entry represents the probability the row message is selected.[16] Note that "better" messages are more likely chosen: "LD" and "HR" are more frequently selected when matched with "NP," and from the pair ("LD","HR") the "HR" message is more frequently selected.

Given the above selection probability matrix we can compute the predicted frequency with which the principal selects a low or high-type agent, for each of the three message types. The chance that an agent is low-type, sends message m, and is selected is given by

$$P_L^{select}(m) = \sum_{m'\in\{\mathrm{NP},\mathrm{LD},\mathrm{HR}\}} \frac{2}{3}P_L(m)\left(\frac{2}{3}P_L(m') + \frac{1}{3}P_H(m')\right)2P^{select}(m,m')$$

where the 2 appears because there are two agents that could have sent the selected message. Analogously, for an agent who is of high type, the probability of being selected after sending message m is

$$P_H^{select}(m) = \sum_{m'\in\{\mathrm{NP},\mathrm{LD},\mathrm{HR}\}} \frac{1}{3}P_H(m)\left(\frac{2}{3}P_L(m') + \frac{1}{3}P_H(m')\right)2P^{select}(m,m')$$

These selection frequencies are shown in the bottom-right panel of Table 4. With competition the overall frequency with which a high-type agent is selected goes up from 33.4 % to 35.7 %, which is not significant.

Finding 8 The possibility of communication does not improve the principal's ability to select the high-type agent in the competition treatment.

[16]For example, the second entry in the top row indicates that 20 % of the time the principal selects the "NP" message from the pair ("NP","LD"). The first entry in the second row shows the "LD" message is selected from such a pair with complementary probability. More generally, the sum of the selection matrix and its transpose yields 1 in all entries since one of the two messages is selected. For the same reason the diagonal elements are 1/2.

For instance, when the principal faced one high-type and one low-type agent, the probability that the high-type agent was selected is only 55 % given the empirical distribution of the three message types sent by the two types of agents (Table 4) and the selection probability matrix. Thus communication does not help the principal to identify the high-type agent. The many "NP" messages also affect the principal's decision to choose "In." Comparing the numbers in the top panels of Table 4 shows that the "In" rate drops from 80 % to 33 % for the "NP" message, from 88 % to 50 % for the "LD" message, and from 90 % to 78 % for the "HR" message.[17] The overall "In" rate significantly drops from 87.2 % in "2C" to 59.5 % in "3C" (see Table 2).

Finding 9 In the communication treatments, the principal chooses "In" significantly less often when competition is introduced.

Interestingly, low-type agents that sent "LD" messages are trustworthy and never "Roll" in treatment 3C. The "Don't Roll" rate conditional on sending a "LD" message is not different from the one in treatment 2C.[18] Aggregating over the different types of messages also shows that the "Don't Roll" rate is not different with and without competition (see Table 2). Finally, the frequency with which selected low-type agents lie (either about their actions or types) is not significantly higher in the treatment with competition.[19] This is consistent with Rode's (2010) finding that lying reflects a stable social preference, which is insensitive to the competitive context.

Finding 10 Low-type agents do not lie more nor are they less trustworthy when competition is introduced.

The selection probabilities together with the observed "In" and "Don't Roll" rates determine the predicted fraction of efficient outcomes, similar to (1). These are shown in the bottom-right panel of Table 4. In particular, the overall predicted fraction of efficient outcomes in treatment "3C" is 37.5 %.[20] This is significantly lower than the corresponding percentages for treatments "3NC" and "2C" (Findings 3 and 4).

To summarize, when competition is introduced, there are fewer messages that reveal ability (Finding 7). This precludes the principal from selecting a high-type agent more frequently than the ex ante probability of 1/3 (Finding 8). In addition, the many "NP" messages cause the principal to be more cautious and she chooses "In" less frequently (Finding 9). Competition thus negatively affects efficiency when communication is present. Finally, the principal would have been better off by choosing

[17] For the "NP" and "LD" messages these differences are significant ($p = 0.04$ and $p = 0.03$ respectively).

[18] The conditional "Don't Roll" rates are 100 % (5/5) and 87 % (13/15) in treatments with and without competition respectively. The difference is not significant ($p = 0.389$).

[19] The percentages of lies are 37.5 % (9/24) and 27.3 % (9/33) in treatments with and without competition respectively. The difference is not significant ($p = 0.412$).

[20] An interesting extension is to let the principal's "In" rate depend on both messages received. In this case, the predicted fraction of efficient outcomes drops to 34.2 % and the difference between "2C" and "3C" is significant at the 5 % level ($p = 0.0475$) and the difference between "3C" and "3NC" is significant at the 10 % level ($p = 0.09$).

"In" more often since the low-type agents are no less trustworthy than in the no-competition treatments (Finding 10).

4 Related experiments and behavioral explanations

The main goal of this paper is to report a replication and extension of Charness and Dufwenberg's (2011) experiment. Of course, there exist a number of other experiments that explore whether cheap talk communication enhances trust.[21] This prior work has demonstrated that individuals trade off the intrinsic cost of lying against the economic cost of truthfulness. To capture this trade off several theories have been proposed, including lie-aversion and various forms of guilt aversion.[22] Likewise, there exist a number of experiments studying the effects of competition on trust.[23] While the results of these experiments are mixed (i.e. competition can have a positive, negative, or no effect), they have inspired several models of other-regarding behavior such as inequality-aversion and reciprocity.[24] Our experiments, which allow for both competition and communication, form an ideal test for these recently proposed theories.[25]

4.1 Guilt aversion

With selfish agents the subgame-perfect equilibrium predicts only inefficient outcomes. The principal chooses "Out" because there is a high chance (2/3) that choosing "In" will result in a zero payoff since selfish agents choose to "Roll" independent of their type. The flip side of this argument is that for the principal to choose

[21] See, for instance, Gneezy (2005), Vanberg (2008), Ellingsen et al. (2009), and Sutter (2009). Charness and Dufwenberg (2010) and Serra-Garcia et al. (2011) study how the results depend on the type of language used by comparing bare versus rich messages and vague versus precise messages respectively.

[22] For models of lie aversion see Ellingsen and Johannesson (2004), Demichelis and Weibull (2008), Vanberg (2008), and Kartik (2009). To model guilt, two notions are offered by Battigalli and Dufwenberg (2007, 2009): simple guilt and guilt-from-blame. Charness and Dufwenberg (2006) and Ellingsen et al. (2010) provide evidence of simple guilt in trust games while Charness and Dufwenberg (2011) test guilt-from-blame.

[23] In repeated trust games that allow for reputation building, Huck et al. (2012) find that competition among trustees significantly improves trust and trustworthiness and, hence, efficiency. In contrast, Fehr et al. (1998) and Brandts and Charness (2004) find that competition does not significantly alter behavior in repeated gift-exchange games. In a one-shot trust game where reputation formation is not possible, Bauernschuster et al. (2012) find that when trustees can select from multiple trustors, the trustor with the highest offered amount is always chosen but is returned a significantly lower amount than trustors receive in a control treatment without competition. Roth et al. (1991) and Grosskopf (2003) investigate how competition affects bargaining outcomes.

[24] See Fehr and Schmidt (1999), Bolton and Ockenfels (2000), Rabin (1993), Dufwenberg and Kirchsteiger (2004), and Falk and Fischbacher (2006).

[25] Rode (2010) is the only paper we are aware of that studies the interaction between communication and competition. In Rode's experiment, pairs of subjects either play a cooperative coordination game or a competitive matching pennies game before being matched with a different opponent in a cheap-talk sender-receiver game. Rode finds that the competitive nature of the initial game does not increase the number of lies but it does decrease trust as it leads subjects to believe that the cheap-talk game is a situation of conflicting interest.

"In," low-type agents would have to choose "Don't Roll" sufficiently often. Charness and Dufwenberg (2011) suggest that one reason why low-type agents might choose "Don't Roll" is to avoid feelings of guilt associated with letting the principal down.

There are two ways to model guilt. One version, called "simple guilt," assumes that a low-type agent's guilt is proportional to the payoff loss she knows she caused. A different version, called "guilt-from-blame," assumes that a low-type agent's guilt is proportional to the payoff loss she believes she can be blamed for by the principal. To illustrate the differences between these two guilt theories, consider the "NDR" and "WDR" versions of no-competition treatments. According to the simple guilt theory, the amount of guilt incurred by a low-type agent who chooses "Roll" is the same in both versions of the game. In contrast, guilt-from-blame predicts that feelings of guilt are less pronounced in the "WDR" version of the game, since a low-type agent cannot be fully blamed for a zero payoff for the principal. Guilt-from-blame thus predicts higher "Don't Roll" rates and, in equilibrium, higher "In" rates in the "NDR" version of the game. Since we find no differences in behavior between "NDR" and "WDR" (see Finding 2), our data are best explained by the simple-guilt theory.

Neither guilt theory, however, can explain the positive effect of competition on efficiency (see Finding 4) since for the selected agent in treatment "3NC" the amount of guilt is the same as in treatment "2NC." In addition, as noted by Charness and Dufwenberg (2011), the reason for the increased efficiency when communication is introduced in the no-competition treatment is "outside the scope" of the simple guilt and guilt-from-blame models.

4.2 Lie aversion

Lie aversion (Ellingsen and Johannesson 2004) relies more directly on the possibility of communication. The basic idea underlying the theory is that an agent who makes a promise incurs a cost $k \geq 0$ when breaking it. In other words, lie aversion transforms cheap talk into costly talk once promises are made. As a result, lie aversion allows for the possibility of a fully efficient equilibrium where low-type agents promise "LD," high-type agents promise "HR," and the principal chooses "In" when faced with an "LD" or "HR" message and "Out" when faced with an "NP" message.[26] Lie aversion can thus explain the increase in efficiency when communication is introduced in the no-competition treatment ("2C" versus "2NC"). However, it cannot explain why efficiency is not higher when communication is introduced in the competition treatment ("3C" versus "3NC"), see Finding 3. Also, it cannot explain the increase in efficiency when competition is introduced in the absence of communication ("2NC" versus "3NC").

4.3 Inequality aversion

When low-type agents are inequality averse they value the "Roll" option less because of the disutility they get from being ahead in terms of payoffs. For example, according to the Fehr and Schmidt (1999) model a low-type agent's utility from choosing "Roll"

[26] For the payoffs of Fig. 1, it is trivial to verify that this is an equilibrium when the cost of lying $k \geq 6$.

would be $20 - 20\beta$ where $\beta \geq 0$ is the inequality-aversion parameter that multiplies the difference between the agent's and the principal's payoff. The low-type agent's utility from choosing "Don't Roll" is simply 14. When $\beta \geq 0.3$, agents would thus have an incentive to choose "Don't Roll" and the principal should choose "In."

Now consider what happens if there is competition between agents. The selected agent now compares her payoff to that of the principal and to that of the agent who was not selected. A low-type agent's utility from choosing "Roll" is now $20 - \frac{1}{2}\beta(20 + 15) > 20 - 20\beta$ while the utility from choosing "Don't Roll" is $14 - \frac{1}{2}\beta(9) < 14$. In other words, the introduction of competition makes the "Roll" option more attractive and the "Don't Roll" option less attractive, resulting in *less* efficient outcomes. Inequality aversion therefore predicts a reduction of efficiency due to competition, which is the opposite of the first part of our Finding 4. Moreover, this outcome-based theory cannot explain the effects of communication in the no-competition ("2C" versus "2NC") and competition treatment ("3C" versus "3NC").

4.4 Reciprocity

Rabin's (1993) reciprocity model is centered around the idea that kind actions trigger kind responses while unkind actions are retaliated. For example, for the extensive-form game in Fig. 1, the principal is kind when she chooses "In" with higher probability and the low-type agent is kind when she chooses "Don't Roll" with higher probability. For the high-type agent, "Roll" is the unique Pareto efficient action since it makes both the principal and the agent better off, and the high-type agent's choice is therefore neither kind nor unkind. The notion that kindness is reciprocated is captured by multiplying the kindness levels of the principal and the agent and adding the result to players' material payoffs, weighted by a reciprocity parameter $\xi \geq 0$.

The reciprocity model allows for multiple equilibria. For example, the fully inefficient outcome in which the principal chooses "Out" and both types of agents choose "Roll" is an equilibrium for all levels of ξ. The reason is that the principal's "Out" choice is unkind so a low-type agent will prefer to "Roll" since this yields higher material payoff and the satisfaction of retaliation. Similarly, the low-type agent's "Roll" choice is unkind and the principal is better off choosing "Out." For high enough reciprocity levels also the fully efficient outcome in which the principal chooses "In," the low-type agent chooses "Don't Roll," and the high-type agent chooses "Roll" is an equilibrium. Now, the principal's choice is kind and the low-type agent prefers to forgo material payoff and respond kindly.

The reciprocity model can thus explain a non-zero fraction of efficient outcomes in the "2NC" treatment. Furthermore, it is the only model that predicts an increase in efficiency when competition is introduced in the no-communication treatments. Since the payoff of not being selected is lower than the payoff of "Out," a low-type agent will want to reciprocate even more when the principal selects her and chooses "In." This results in higher "Don't Roll" rates and, hence, higher "In" rates. As pointed out by Charness and Dufwenberg (2006), however, the reciprocity model may have a hard time explaining the positive effects of communication. Suppose, for example, that in treatment "2C," a low-type agent promises not to "Roll." If the principal believes the promise then her "In" choice is not considered as kind as when this choice is made in the treatment without communication.[27]

5 Conclusions

There are two important conclusions to take away from our experimental results. The first one concerns the fragility of cheap-talk communication. We replicate recent findings by Charness and Dufwenberg (2011) that communication is efficiency improving when a single agent sends messages to a principal. However, this positive effect of communication is absent in our treatment with agent competition.[28] The second conclusion concerns the theoretical models, some of which originated to explain the positive effects of communication in bilateral settings. We review several leading alternatives, including lie aversion, guilt aversion, inequality aversion, and reciprocity, and find that each of them captures important aspects of the data that a model with standard preferences cannot. However, none of the models by themselves can explain the substitute patterns between competition and communication that we observe in the experiments.

Of course, this does not imply that the models are wrong—it is only natural to presume that several factors are at work. It does imply, however, that more empirical work is needed to gauge the relative importance of the proposed behavioral factors. Our study is only a first step and there are many other directions worth exploring. One natural question to ask is whether communication and competition act as substitutes in other environments. For example, will competition between agents reverse the positive effect of communication in Charness and Dufwenberg (2006)'s one-shot trust game with hidden action?[29] Does an increase in the number of traders in a market make communication more or less effective, and, vice versa, does the possibility of communication reinforce or undermine the positive effects of an increase in competition?[30] How are charitable donations affected when multiple recipients can plead their cases to a donor?

Communication also plays an important role in group participation games such as voting. For instance, depending on the degree of asymmetry in group sizes, does communication attenuate or exacerbate the "underdog" effect, i.e. the tendency of minority group members to participate more frequently than majority-group members? Likewise, does communication reinforce the "competition" effect that predicts increased participation rates when the degree of group-size asymmetry becomes

[27] Indeed, if the principal believes that the agent will choose "Don't Roll" with probability one then her "In" choice is the unique Pareto efficient action, which entails zero kindness. As a result, the low-type agent has no incentive to keep the promise.

[28] Communication can be efficiency improving with more than two people if they have a common objective as is the case, for instance, with jury decision making (Goeree and Yariv 2011).

[29] Goeree and Zhang (2013a) documents significant efficiency-enhancing effect of communication with or without competition.

[30] Preliminary evidence suggests that cheap-talk works well in bilateral bargaining but not in markets with a larger number of traders (Goeree and Zhang 2013b).

smaller? Finally, how does communication interact with the "size" effect, which predicts that keeping fixed the relative group sizes, participation rates fall when groups get bigger?[31]

Another avenue worth investigating is how the communication protocol affects its efficacy. In this paper we considered only one-way communication from the agent(s) to the principal. It would be interesting to explore whether two-way communication would undo or strengthen the substitute effects of competition and communication.

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